

EQUATIONS, EQUATIONS

Calculate and convert

Harry Baggen

Electronics is not always plain sailing. Although a small circuit can be built quickly without jotting down complex formulas, a deeper or more theoretical approach soon calls for equations and basic maths. There is no need however to know everything from the top of your head as the Internet is available to assist.

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Handbook of Mathematical Functions

with

Formulas, Graphs, and Mathematical Tables

Edited by Milton Abramowitz and Irene A. Stegun

1. Introduction

The present Handbook has been designed to provide scientific investigators with a comprehensive and self-contained summary of the mathematical functions that arise in physical and engineering problems. The well-known Tables of Functions by E. Jahnke and F. Emde has been invaluable to workers in these fields in its many editions¹ during the past half-century. The present volume extends the work of these authors by giving more extensive and more accurate numerical tables, and by giving larger collections of mathematical properties of the tabulated

tional importance. Many numerical examples are given to illustrate the use of the tables and also the computation of function values which lie outside their range. At the end of the text in each chapter there is a short bibliography giving books and papers in which proofs of the mathematical properties stated in the chapter may be found. Also listed in the bibliographies are the more important numerical tables. Comprehensive lists of tables are given in the Index mentioned above, and current information on new tables is to be found in the National Bureau

Electronics can be downright easy... but also horrendously difficult. Once you've mastered a few basic 'laws' and have an idea of the operation of a number of passive and active parts, you'll get remarkably far in designing a circuit. However, far more learning is in order for a theoretical approach or more accurate calculations on electronic circuits. Soon, you may feel drowned in formulae and equations and the fun wears off quickly. Those of you who have completed a formal education in electronics probably don't have to be told how complex a circuit design can turn out to be.

In addition to a solid base in electronics and mathematics there are many bits of knowledge you do not need every day — just think of the horrors of a Laplace transformation or a

Fourier series. In those cases it is useful to have an overview handy of where to find such subjects. Sure, they are covered in electronics textbooks, but where exactly?

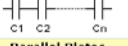
The Internet contains nice compilations of calculations for a multitude of electronics subjects. Even if you do not have your maths ready just there and then, it is good to know you can almost instantly refresh your memory. A good base for such a 'calculus collection' is found at the **RF Cafe** [1]. Right at the top of the homepage you'll find a table that begins with *Equations & References*. Below it you can click on two links, *Electrical* and *General*. Both supply an alphabetical list of technical subjects, where the first is of course the most interesting to us. Although the RF Cafe is mostly dedicated to high frequency (radio) design, this overview does not fail to cover a much wider range: from the size of miniature bulbs right up to the design of PCB microstrips. Even browsing around in this overview will soon enable you to pick out some really useful bits like the elementary calculations for various passive components and all filter transfer functions. Not forgetting, of course, copper wire gauge comparison tables and resistor series. The more RF inclined among you will certainly appreciate the VSWR calculations and the Smith chart.

Nearly all subjects have their own page in the RF Cafe website. Some links head off to other websites, unfortunately including some dead ones. However, the amount of ready to use information crammed into the website is such that these errors can be excused. On the *General* page you'll find general-purpose information like bolt & nut sizes, the Greek alphabet, global timezones, sound properties in different materials, thermocouples and heatsink calculations just to mention a few. Although the *Calculator* section contains several links to commercial software packages, it does include lots of nifty calculation programs for direct use.

The RF Cafe has lots more to offer, particularly of course on RF design. We'll hold the subject over to another instalment of electronics online; else we should have called this instalment 'RF Cafe' straight way! There's one link however we simply must tell you about: on the *Electrical Conversions, Formulas & References* page is a reference to the entire (scanned) *Handbook of Mathematical Functions*, a more than 1,000 pages thick standard textbook containing just about any formula, graph and table we could think of. The entire book (originally published in 1964) is available free of charge from **ConvertIt** [2].

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Series Capacitors

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n}$$


Parallel Plates



$$C = \frac{\epsilon_0 \epsilon_r A}{D}$$

$$W = \frac{1}{2} C V^2$$

$$i(t) = C \frac{dv(t)}{dt}$$

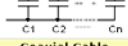
$$v(t) = \frac{1}{C} \int i(t) dt + v_0$$

$$X_C = \frac{1}{2\pi f C}$$

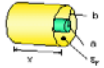
$$C = \frac{q}{V}$$

$$D.F. = \frac{1}{Q}$$

Parallel Capacitors

$$C_p = C_1 + C_2 + \dots + C_n$$


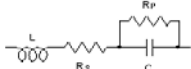
Coaxial Cable



$$C = \frac{2\pi\epsilon_0\epsilon_r x}{\ln(b/a)}$$

A = Area of plates
 C = Capacitance (F)
 D = Distance between plates (m)
 a = Inner radius (m)
 b = Outer radius (m)
 q = Charge (Coulombs)
 x = Length (m)
 W = Energy (J)
 ϵ_r = Relative permittivity
 $\epsilon_0 = 8.85 \times 10^{-12}$ F/m
 $D.F.$ = Dissipation Factor = $1/Q$

Equivalent Capacitor (total model)



Old Capacitor Color Code Chart

Color	Significant Figure	Decimal Multiplier	Tolerances	Voltage Rating
Black	0	1		100 volts
Brown	1	10	1%	
Red	2	100	2%	200 volts
Orange	3	1,000	3%	300 volts
Yellow	4	10,000	4%	450 volts
Green	5	100,000	5%	500 volts
Blue	6	1,000,000	6%	600 volts
Violet	7	10,000,000	7%	700 volts
Grey	8	100,000,000	8%	800 volts
White	9	1,000,000,000	9%	900 volts
Gold		0.1	5%	1000 volts
Silver		0.01	10%	2000 volts
No Color			20%	500 volts

Color	Significant Figure	Multiplier	Tolerance	Temp. Per. Change	Temp. Coefficient
Black	0	1	±20	±5.0ppm/°C	0
Brown	1	10	±1	±2.5ppm/°C	-50
Red	2	100	±2		-40
Orange	3	1,000			-100
Yellow	4				-250
Green	5				-350
Blue	6				-450
Violet	7				-550
Grey	8				-650
White	9				-750
Blue		0.01	±5.0ppm/°C		0
White		0.1	±1.0ppm/°C		-350
White		0.1	±1.0ppm/°C		500

Internet addresses

- [1] RF Cafe:
<http://www.rfcafe.com/references/electrical.htm>
- [2] Handbook of Mathematical Functions:
<http://www.convertit.com/Go/ConvertIt/Reference/AMS55.ASP>

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- Microstrip Equations -

You can work these formulas manually, or download this great free calculator ([TX Ling](#)) from AMR.

Effective Width and Height

$$W_{eff} = W + \frac{1}{\pi} \left(\ln \left(\frac{2h}{1} \right) + 1 \right)$$

$$H = h \cdot 2t$$

wavelength

$$\lambda = \frac{c}{f \sqrt{\epsilon_{eff}}}$$

phase

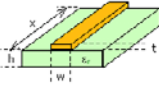
$$\theta = \frac{2\pi}{\lambda}$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \frac{1}{1 + 12 \left(\frac{H}{W} \right)}$$

$$Z = \frac{120 \pi}{\sqrt{\epsilon_{eff}} \left[\frac{W}{H} + 1.393 + \frac{2}{3} \ln \left(\frac{W}{H} + 1.444 \right) \right]}$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \frac{1}{1 + 12 \left(\frac{H}{W} \right)}$$

$$Z_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \frac{1}{1 + 12 \left(\frac{H}{W} \right)}$$



$\frac{W}{H} \gg 1$

$\frac{W}{H} \ll 1$